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14. ABSTRACT Several different aspects of numerical methods for electromagnetic scattering are considered. The interior source method is onemajor focus of the research. It is shown how the scattered field can be extended to the interior of a scatterer with a view to determining the locations of singular points of the extended field. These results are of immediate use to synthesise the scattered field. The interior source method has been applied to solving a number of scattering problems, mostly but not exclusively from smooth bodies. Spectral convergence of the approximations has been demonstrated and this permits far fewer unknowns to be used in the computation than would be the case with methods in which the sources are distributed on the boudary of the scattering body. A second topic of research concerns the finite difference time domain technique (FDTD). For this method a new approach to handling complex geometrical situations has been developed. This approach uses a least squares technique in conjunction with a novel but simple form of description of the boundary of the body. It converges at or close to a rate of second order in the spatial variables in contrast to a number of other algorithms designed to solve the same problem.

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1 Extension of solutions of Helmholtz's equation.

In interior source methods in computational electromagnetics, a set of sources is placed inside a scattering body and the fields which the sources create is matched to the incident field on the boundary. The sources all lie strictly inside another body (which is strictly inside the scatterer). Call this body B'. The field created by the sources is analytic outside B', because there are no sources in that region, and it approximately matches the incident field on the scatterer surface (exactly in the limit as the number of sources approaches infinity). In addition the field of the sources is outgoing since that is a property of the sources themselves. By uniqueness theorems the field of the sources approximates the scattered field outside the scatterer. It follows from what has been said that the field of the sources constitutes an extension of the exact scattered field to the inside of the scatterer, at least up to the boundary of B'. A very important issue which arises is then whether the analytic extension of the exact scattered field has any singularities outside B'. If it does then the interior source approximation may only converge in a rather weak sense. In practice the approximations experience large oscillations which average out to the correct values. In this section of the research we showed how to accurately locate the singularities of the extended scattered field without ever knowing the scattered field itself. The calculations are analytical and often quite tractable. In addition to providing insight into the scattering process itself our result gives explicit information about where to locate the sources to achieve maximum accuracy. This work is reported in the paper

" Extendability of solutions of Helmholtz's equation to the interior of a two dimensional scatterer, (Joint with R. Kangro and U. Kangro) Quarterly of Applied Mathematics, 58,3,(2000),p591

2 Handling complex geometries in finite difference solutions of Maxwell's equations.

Although there is a version of the FDTD method which is defined for arbitrary triangular and tetrahedral meshes (introduced first by the author) there remains a great deal of interest in using the rectangular version of the algorithm even when complex geometry is involved. To handle complex geometries using rectangular meshes several alternatives have been proposed and are in use. Unfortunately, there are situations when these techniques can be unsatisfactory. This is unsurprising given that even for far simpler elliptic and parabolic equations the same problem has never been satisfactorily solved (hence the success of finite elements). In this research we have introduced a new and promising technique for handling complex geometries using rectangular meshes. The distinguishing fearure of our approach is that it does not modify the mesh near the boundary of the domain. Only the standard mesh is used. The basic problem with implementing this idea is that there is a mismatch between the number of boundary points and equations. It is natural to try to use least squares to circumvent the mismatch but then further difficulties occur in the inner equations. Our method shows how these difficulties may be neatly avoided. The net effect is an algorithm which requires only a description of the boundary for a regular mesh implementation. Implementations of the new technique show that it is close to second order accurate even for problems which have singular fields on the boundary of the domain, for instance corner singularities. This work is reported in the paper

"A Method to Handle Complex Geometries in Finite Difference Solutions of Maxwell's Equations" (Submitted to IEEE Transactions on Antennas and Propagation).

3 Interior source techniques for three dimensional electromagnetic scattering.

Section 1 above explains the ideas behind the interior source method for solving scattering problems. Most applications have been for two dimensional problems. In this project we implemented a three dimensional version and analysed its behavior. The interior source functions were taken to be electric dipoles. The implementations showed that the interior source method has considerable advantages in situations where the scatterer is smooth. In that situation the method performs best and high wavenumber scattered fields can be computed very efficiently compared with alternative techniques. Our work provides a theoretical explanation for this behavior and supplies guidelines on how to distribute the sources and on the effrct on accuracy of different types of distribution. For instance there are questions about whether the full exponential accuracy is attained when the inner sources are distributed on

surfaces which are not smooth, having edges and corners. Our calculations show that this is acceptable in a practical sense. When the scatterer itself has edges and corners the performance of the interior source method can degrade if it is not well implemented. These questions were investigated also. The work is reported in the paper

"Interior source techniques in three dimensional electromagnetic scattering", (joint with U. Kangro) (to be submitted to the Journal of Computational Physics)

4 An additional publication

Early in the grant period a computational electromagnetics workshop was organized by the PI. The proceedings of this workshop are contained in the book

"Computational Electromagnetics and its Applications" Eds. T. G. Campbell, R. A. Nicolaides and M. D. Salas, Kluwer Academic Pub. 1997.